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Technical Report

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TO: Office of Grants and Research Contracts
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National Aeronautics and Space Administration
Washington, D. C. 20546

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1. The grant NGR-33-016-066 entitled ("Study of High Energy Nuclear Reactions and Space Radiation Shielding"), originally expiring on March 1, 1966, has been extended (NGR-33-016-066 Supplement No. 1) to August 31, 1966. This technical report may, therefore, be regarded either as a semi-annual report for the entire grant which will expire August 31, 1966, or as a report for the initial one-year period of the grant ending in March 1966. Our previous technical report was dated September 1, 1965.

2. At this writing, we have performed under this research project a total of five experiments at the 3-GeV accelerator (Cosmotron) at Brookhaven National Laboratory. The five experiments are:

Experiment A: 2.9 GeV protons on a Lucite ($C_5H_8O_2$) target;

Experiment B: 2.2 GeV protons on a Lucite target;

Experiment C: 1 GeV protons on a graphite target;

Experiment D: 1 GeV protons on an aluminum target;

Experiment E: 1 GeV protons on a copper target.

3. In Experiments A and B, the Lucite target was 1 ft x 1 ft x 30 gcm^{-2} thick. The focused external proton beam of the Cosmotron strikes the target at normal incidence at the center of the 1 ft x 1 ft end. The primaries together with the secondaries produced by nuclear reactions in the target were roughly assayed by means of the activation of 1 ft x 1 ft aluminum foils sandwiched at various depths inside the Lucite target. The fluorine-18 (2 hours) and sodium-24 (15 hours) activities produced by high-energy and fast-neutron reactions in the aluminum foils were assayed. This method of studying the radiation in a thick target was developed in our earlier work (Ref. 1, 2, and 3). The detailed analysis of the data from Experiments A and B is still in progress. Preliminary results (Ref. 4) indicate that the measured activities in the aluminum foils increase with depth in the target and attain a broad maximum near the downstream end of the target. Unlike the usual transition maximum expected in thicker targets, this "premature" maximum is apparently caused by the lack of backward-moving particles near the downstream end of the 30 gcm^{-2} target.

4. In Experiments C, D, and E, the geometry of irradiation is as shown in Figure 1. A thin target was irradiated in the focused external 1-GeV proton beam of the Cosmotron. The target material was carbon (graphite), aluminum, and copper, respectively, in Experiments C, D, and E. These target materials were chosen for

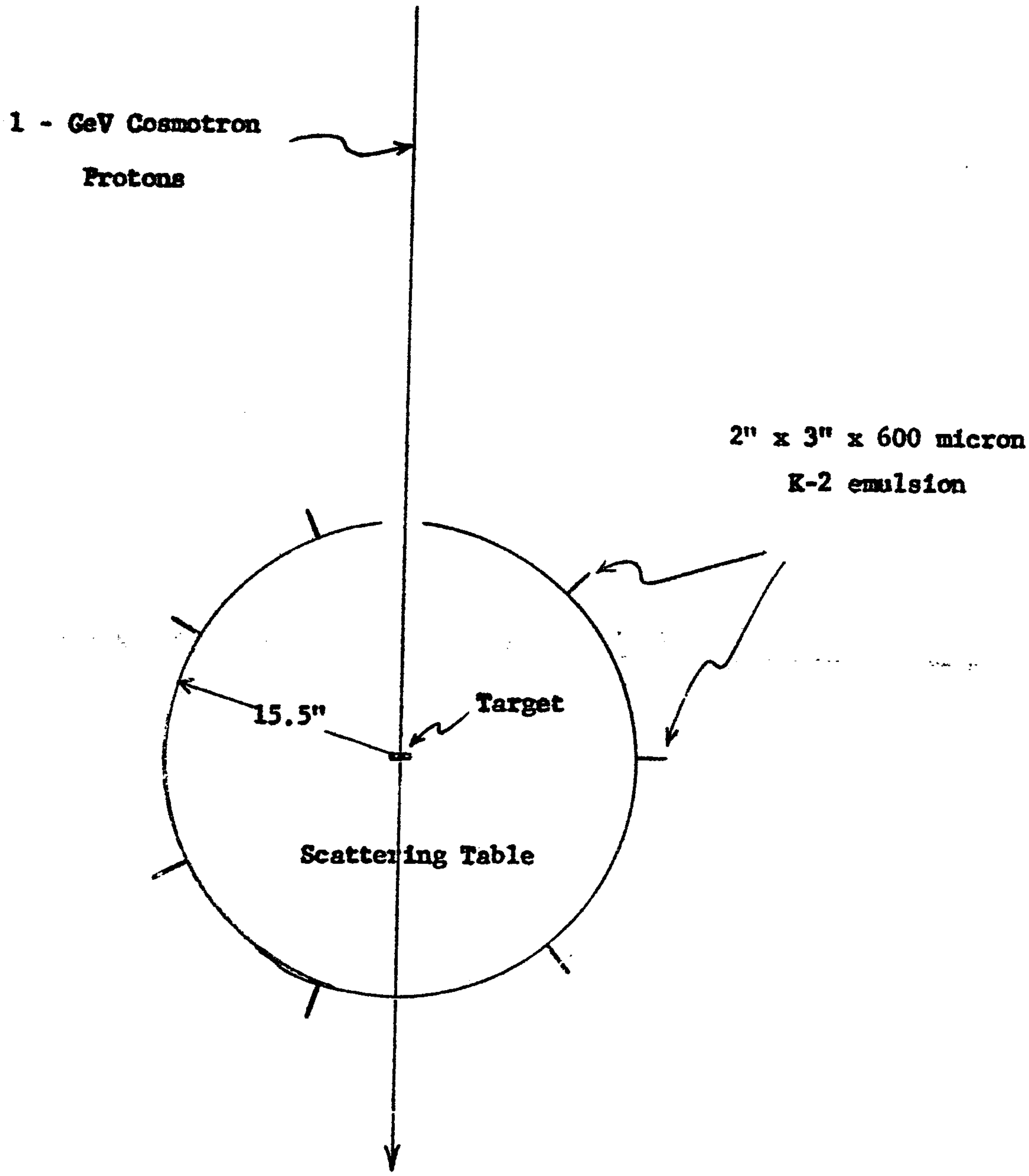

FIGURE 1. Irradiation arrangement for Experiments C, D, and E. Only a few of the emulsions used are shown in this diagram.

their significance to astrophysics, to shielding physics, and to nuclear-structure studies. Ilford K-2 emulsions were arranged radially around the target (only a few representative emulsions are shown in Figure 1). The K-2 emulsions are not electron-sensitive, so that relativistic charged particles do not leave distinguishable tracks in the emulsion. Thus, as intended, relativistic protons and pions emitted from the bombarded target nuclei are not recorded in the emulsions. Neutrons emitted from the target nuclei, on the other hand, have a chance to make recoil protons upon collision with the hydrogen in the emulsion. These recoil protons leave tracks that can be detected and measured in detail, and conclusions about the fast neutrons that produced them can be drawn. One of the problems in using emulsions in these experiments is the possibility of over-exposing the plates, resulting in over-crowded tracks. Since we had no firm guide as to the proper beam exposure to use, three sets of emulsions were exposed in each experiment, each set being exposed for a different duration to the proton beam. In this way, it is expected that one of the three sets would give a track density convenient for detailed measurements. At this writing, most of the emulsions from Experiments C, D, and E have been developed using a special process worked out at the AEC Health and Safety Laboratory. Scanning of the emulsions will begin in the near future.

5. We wish to take this opportunity to acknowledge the support of

this research by NASA. We also wish to thank J. E. McLaughlin, K. O'Brien, and R. S. Sanna of the U.S.A.E.C. Health and Safety Laboratory for their valuable scientific collaboration. Thanks are also due to Raymond Davis, Jr., Senior Chemist at Brookhaven National Laboratory, for his kind cooperation and advice. The unfailing cooperation of the Cosmotron staff, particularly A. Enright and W. Glenn, is also greatly appreciated.

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